RENEWABLES AND COAL: CO-FIRING FOR GREATER EFFICIENCY

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He has held a range of positions in the power industry including in Power Project feasibility assessment and development, Power Station Construction, Environmental Management and Water and Waste Water Treatment.

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Coal Utilisation and the Environment

Renewables and Coal: Co-firing for greater efficiency

Abstract

This paper considers the use of co-firing biomass with coal as a greenhouse gas (GHG) reduction strategy, in an Australian context. Co-firing is compared with other renewable technology options for generating electricity and found to be competitive but limited by the location of appropriate fuel sources. A number of Life Cycle Analysis (LCA) studies are reviewed which demonstrate that using 5 percent biomass (by energy) for co-firing that would otherwise have gone to landfill could reduce GHG emissions by 5 percent. If this biomass is replaced by re-growth GHG emissions could be reduced by up to 10 percent.

Co-firing was found to provide positive benefits for sulphur and nitrogen emissions. Consideration is given to the need for regulation to provide appropriate focus on fuel types and ensure use of renewable and sustainable fuel sources. Finally, some practical outcomes of co-firing plant tests at Delta Electricity's Wallerawang power station are reviewed.

Introduction

The basic concept of co-firing, or co-combustion as it is also known, is to supplement the coal supply to a furnace with small quantities of low cost opportunity fuels such as Refuse Derived Fuel (RDF) or old tires, or renewable fuels such as sustainably harvested biomass material. In the case of renewable fuels co-firing provides the advantage that existing infrastructure such as coal fired power plant may be used to produce renewable energy and reduce greenhouse gas emissions.

The supplementary fuels used for co-firing usually have a lower energy content than coal and can also contain up to 50 percent moisture content. These characteristics mean that the conversion efficiency of the supplementary fuel is usually less than that of coal. However, one aim of co-firing is to substitute some coal with a less greenhouse intense fuel. This could be achieved by using the renewable fuel in a purpose built biomass fired power station or utilising it in large coal fired plant. Because of their scale large coal fired power plant usually have much higher conversion efficiency than small biomass fired plant. Typically, a coal fired plant utilising high temperatures and pressures and a reheat cycle may operate in the conversion efficiency range from 34 to 38 percent where as the economies of scale of a small biomass fired plant dictate lower temperature and pressures and less sophisticated thermodynamic cycle. In which case small dedicated biomass plants typically deliver thermal efficiency in the range 20 to 25 percent. As a result co-firing with coal provides greater efficiency than utilising small scale stand alone plant and could produce up to 50% more electricity from the same fuel input.

Co-firing can be either direct or indirect (1). For direct co-firing the supplementary fuel is combusted directly in the furnace and is either conveyed into the furnace with the coal or delivered via a purpose built burner. Direct co-firing is usually used for clean, homogenous fuels such as wood or agricultural wastes. In-direct co-firing usually involves gasification of the supplementary fuel in a separate gasification facility. The synthesis gases are then co-combusted in the coal fired furnace. Indirect co-firing is more suited to fuels containing contaminants such as those derived from municipal waste streams since the synthesis gas can be purified prior to it's use.

Fuel selection is critical if co-firing is to be environmentally acceptable and successfully reduce greenhouse gas emissions. Biomass fuels ultimately derive their energy content from the sun via photosynthesis, however for the fuels to be considered renewable they must be sustainably harvested. Plant re-growth must remove an equivalent amount of carbon from the atmosphere to that released when the fuel is burnt to close the carbon cycle.

<u>Co-firing from an Australian Perspective</u>;

Until recently Co-firing supplementary fuels with coal had not been considered an option in Australia as it has abundant supplies of low cost coal. However the Commonwealth Government have recently introduced a range of measures aimed at reducing Australia's greenhouse gas production. These include requirements for electricity generators to meet new efficiency & greenhouse targets, and for electricity retailers to meet renewable electricity sales targets. This second measure is known as the Renewable Energy Act. Under the Act each mega watt hour of electricity produced also generates a renewable energy certificate (REC) which is a tradable right. Each year electricity retailers must accumulate a prescribed number of RECs or pay a penalty to the Government. The Act has had the effect of increasing the price paid for renewable electricity to around twice that of electricity from conventional sources.

The Renewable Energy Act recognises a range of renewable energy sources including wind, solar, wave, hydro which does not require new dams, and bioenergy produced from sustainably harvested biomass fuels.

Chart 1 shows the typical costs of production from various renewable energy sources. Note that biomass typically provides a lower cost of production than alternatives such as wind or solar. The principle reason for this is that biomass power plants operate continuously where as wind and solar are intermittent. Hence the capital utilisation factor for biomass power plant (70 to 80 percent) is typically twice that of wind power (30 to 40 percent).

Utilising existing coal fired power plant to produce renewable energy by co-firing biomass has the added advantage that very little capital investment is required and high thermal conversion efficiencies can be achieved. Hence co-firing can provide a competitive source of renewable energy, particularly if it is direct fired.

The location of existing coal fired power plants relative to potential biomass fuels supplies is an important element for co-firing. The bulk density of Biomass fuels is quite variable typically around half that of coal. The energy content on an as delivered basis is also around half that of coal. The combination of these two factors means that four truck loads of biomass are required to deliver the same energy content as a truck load of coal. These factors mean that the transport cost per unit of energy delivered is significant and has a major influence on the source, type and price of fuel used.

The ultimate effect of this is that is biomass fuels in Australia tend to be low value by-products of value added processes, available at low or no cost. There are a number of environmental benefits as a consequence since what was once a waste material is being redirected to produce energy. The alternative disposal option for some of this waste material is in landfills, ultimately breaking down to produce methane, a potent greenhouse gas.

Delta Electricity is currently developing a co-firing program at it's Wallerawang power station in New South Wales, about 200 km west of Sydney. The plant consists of two, 500MW pulverised coal generating units. The biomass fuel includes saw mill residual, a by product of sustainable plantation operations. We are also investigating the use of construction and demolition wood waste which currently finds its way to landfill in Sydney. Using the material to produce energy has a number of environmental benefits including preventing the material breaking down to methane, and promoting recycling of some of the wood waste stream.

Fuel supplies for co-firing will provide a market for low value wood waste but also provide a cash flow to support recycling businesses sorting the wood waste stream. As a result more timber will be recovered for reuse.

Greenhouse Gas Life Cycle Analysis

How effectively does co-firing reduce greenhouse emissions. There have been a number of Life Cycle Assessments (LCA) of biomass co-firing in coal fired power plants conduct world wide. LCA analysis considers carbon emissions throughout the life of an operating plant taking account of carbon arising from energy use for construction, energy consumption in coal mining and actual plant emissions from coal combustion. The analysis also considers carbon emissions arising from biomass utilisation, accounting for the carbon released when the biomass is transported and burned balanced against the carbon sequestered by replacement plant growth. One particularly difficult element to measure are the emissions savings which result in the avoidance of waste material forming methane in land fills.

The National Renewable Energy Laboratory in the USA (2) a has conducted a sensitivity analysis taking into account a number of factors effecting the amount of methane and CO2 that is avoided by co-firing biomass. These include:

- The split between how much of the biomass goes to landfill
- The extent of degradation of biomass in landfills
- The amount of landfill gas that is captured
- The conditions under which the mulch decomposes

Based on a co-firing operation of 15% biomass fuel input (on an energy basis) the research concluded that if all carbon is actually sequestered in landfill the greenhouse reduction from co-firing is only around 3%. However, if it is assumed the carbon decomposes in landfill the GHG saving is at least 8%.

The laboratory found an average greenhouse gas reduction of 5.4% was possible when co-firing at 5% by heat input and 18.2% when co-firing at 15% by heat input. The study does not allow a credit for the absorption of carbon dioxide during the plant growing cycle as it assumes the biomass used is not grown for the purpose of co-firing. Chart 2 shows the results of the study and comparative greenhouse with other technologies.

Another LCA study conducted in Australia (3) found that greenhouse gas savings of approximately 10% were possible when co-firing biomass at 10% by energy input. Importantly this study assumed that the biomass used came from renewable sources and gave credit for carbon dioxide absorption during the plant growing cycle. It made no allowance for greenhouse gas reductions through avoided landfill.

Combining these two cases, it may be possible to achieve greenhouse gas reductions of 10% when co-firing 5% biomass from renewable plantations that would otherwise have found it's way to landfill. An example of this type of biomass is saw mill wastes, produced from plantation timber.

Regulations for Fuel Use

Use of biomass fuel for the production of renewable energy is regulated in Australia. A certain level of regulation is essential to ensure that the fuel is renewable and credit can be taken for carbon dioxide absorption in the plant growing cycle. Regulation also ensures the use of biomass fuel does not promote unsustainable activities such as forest clearing or destruction of wildlife habitats, and does not contain contaminants which may produce environmentally unacceptable combustion by-products. Regulations also help to focus the choice of fuels on waste materials which would otherwise find their way to landfill.

Typical regulations regarding the renewable nature of the fuel require it to be produced from:

- non-native environmental weed species; or
- a manufactured wood product or a by-product from a manufacturing process; (*Eg* Packing cases, pallets, recycled timber). or
- waste products from the construction of buildings or furniture, including timber off-cuts and timber from demolished buildings; or
- sawmill residue; or
- a by-product (including thinnings and coppicing) of a harvesting operation that is undertaken in accordance with ecologically sustainable forest management principles.

Wood waste from a plantation must be a product of a harvesting operation for which no product of a higher financial value than biomass for energy production could be produced at the time of harvesting. It is the power producers responsibility to maintain records demonstrating that fuel used to produce renewable energy has been derived from these complying sources.

Fuel Quality Assurance

Quality assurance procedures to ensure low levels of environmentally hazardous contaminants in fuel supplies are essential for a direct co-firing operation, particularly when considering the use of manufactured wood products or construction wastes as these may contain timber treated with copper, chromium and arsenic. These elements may not be completely removed in the flue gas cleaning equipment normally fitted to coal fired power plant. Delta Electricity in conjunction with the University of Newcastle is developing testing procedures that ensure unacceptable levels of contaminates are detected before the biomass fuel is delivered to the power station.

The test process will require each batch of waste wood to be analysed for copper, chromium and arsenic after being shredded, prior to it leaving the processing facility. Source testing is expected to be more effective than flue gas monitoring of emissions for these elements, firstly as it detects them before they enter the furnace and secondly the levels in flue gas are expected to be close to the levels of detection due to the dilution effect when small quantities of biomass are used with coal, and thus impractical to sample for in the flue gas.

Emission when Co-firing

A significant amount of work has been done on the impact of co-firing on NOx, SOx and particulate emissions from coal fired power plant. As an introduction to this issue it is worth comparing typical biomass analysis with coal.

Ultimate Analysis (% DAF)					
	Urban Wood	Mill Residues	Forest Residues	Ag Residues	Australian Coal
Carbon	51.77	51.39	49.42	50.25	83.71
Hydrogen	6.27	6.12	6.01	5.87	5.31
Nitrogen	0.14	0.26	0.06	0.21	1.86
Oxygen	41.81	42.16	44.48	43.65	8.24
Sulfur	0.01	0.06	0.04	0.02	0.80
Chlorine	0.00	0.00	0.00	0.00	0.08
Moisture (as fired)	15.02	44.92	43.72	38.61	6.00
Ash (as fired)	6.00	2.00	3.00	4.00	22.50
Specific Energy (MJ/Kg) (dry)	19.34	19.72	19.01	18.70	26.60

Biomass fuels contain much less sulphur than coal, usually less than 0.1%. Blending biomass with the coal feed reduces sulphur emissions as a function the blend ratio and the sulphur concentration in the respective fuels. It is a linear relationship, with the result that co-firing biomass fuels reduces SOx emission levels.

NOx emissions are more difficult to anticipate. The nitrogen content of biofuels varies quite widely and may be a function of the type and quantity of fertiliser used in their production. Wood usually has very low levels of nitrogen, less than 0.3 percent with herbaceous fuels, such as grasses, sometimes approaching 1 percent. The behavior of biomass fuel nitrogen may also be expected to be influenced by the availability of oxygen inherent in the biomass fuel to form NOx, even in fuel rich combustion. Research in this area has concluded that there is insignificant chemical interaction between the offgases from biomass and coal that would alter NOx emissions (4). In addition it has found that NOx emissions from wood residues are generally lower than those from coal, leading to some overall reduction in NOx levels when co-firing.

Testing carried out by Delta Electricity's in it's own power stations support these findings.

There does not appear to be any consensus as to the effect of co-firing on particulate emissions. Biomass fuel normally contains less than a quarter of the ash levels common in coal and some times as low as 10 percent of these levels. Intuitively this would suggest that co-firing would reduce particulate emissions.

However, there have been reports that particulate emissions have actually increased on plants operating electrostatic precipitators. On trials conducted at a Delta power station fitted with electrostatic precipitators the particulate emission was found to increase when co-firing, although the emission level was still well within required environmental limits. This increase also appeared to be a function of an increase in unburned carbon in the fly ash. It may be that the ability of the carbon particles to carry a high electrical charge is effecting precipitator operation. In subsequent tests measures were taken to improve carbon burn out rate, with a resulting improvement in particulate emissions.

Operational Issues

Delta Electricity has conducted a range of co-firing trials using wood based fuels at its Wallerawang power station. The program has involved direct co-firing of saw dust and chips from saw milling operations using plantation radiata pine. Levels of up to 7 percent wood waste by weight have been successfully fired. From this experience we can categorise the operational issues associated with co-firing into three areas; i) moisture content of the fuel, ii) particle size and burn out rate, iii) fouling, slagging and corrosion issues.

Moisture is of course a source of efficiency loss. However, high moisture levels have been found to lower the operating temperature of the coal pulverising mills, which in turn limits the quantity of biomass which can be co-fired. Typically a maximum of 50 percent moisture can be tolerated.

Particle size and burn out rate can impact on particulate emissions, as described above, and carbon in ash hence process efficiency. When direct co-firing coal pulverising mills are used to reduce the biomass particle size. These are designed for a crushing action appropriate for brittle materials where biomass size reduction requires shearing action. Despite this we have found that the vertical spindle type pulverising mills are reasonably efficient in reducing the size of biomass when fed with the coal at less than 5 percent by weight. It is suspected that the shearing action required is provided by the coal crushing into the wood fibres.

The pulverised biomass has been found to have a broad particle size distribution as it's low density allows biomass particles larger than coal to by-pass the coal mill particle size classification system. The larger particles burn out more slowly. This problem can be managed by selectively feeding biomass via the coal mills which feed burners lower down in the furnace, effectively allowing the particles to remain in the furnace longer.

To date we have not had any difficulties with fouling, slagging or corrosion, although there is an ongoing need to for monitoring. Fuels containing high levels of alkali metals such as potasium and sodium are susceptible to cause fouling and slagging. Generally fuels with high levels of chlorine should also be avoided as this is has been identified as the main cause for corrosion.

Conclusions

Co-firing biomass with coal offers power plant operators a practical and economic way of reducing greenhouse house gas emissions for power plants located near appropriate fuel supplies. In most cases co-firing will reduce suplhur emissions and depending on the type of fuel used can lower NOx emission levels. If co-firing is to be effective and accepted as a greenhouse reduction strategy the source of fuel must be carefully chosen to ensure that the fuel is renewable and the use of biomass fuels does not promote unsustainable activities such as forest clearing or destruction of wildlife habitats.

References

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(2) Margaret K. Mann, Pamela L. Spath: *A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant*. National Renewable Energy Laboratory, Golden, CO

(3) ACARP Project 8049, entitled “Environmental Credentials of Coal”.

(4) Allen Robinson, Larry Baxter, Helle junker, Chris Sahddix, Sandia National Laboratories, Combustion Research Facility, Livermore, CA, Mark Freeman, Robert James, Federal Energy Technology Center, Pittsburgh, PA, David Dayton, National Renewable Energy Laboratory, Golden Co: *Fireside Isuses Associated with Coal-Biomass Cofiring*, BioEnergy “98: Expanding BioEnergy Partnerships

Chart 1. Cost of Production From Various Technologies ($AUS)

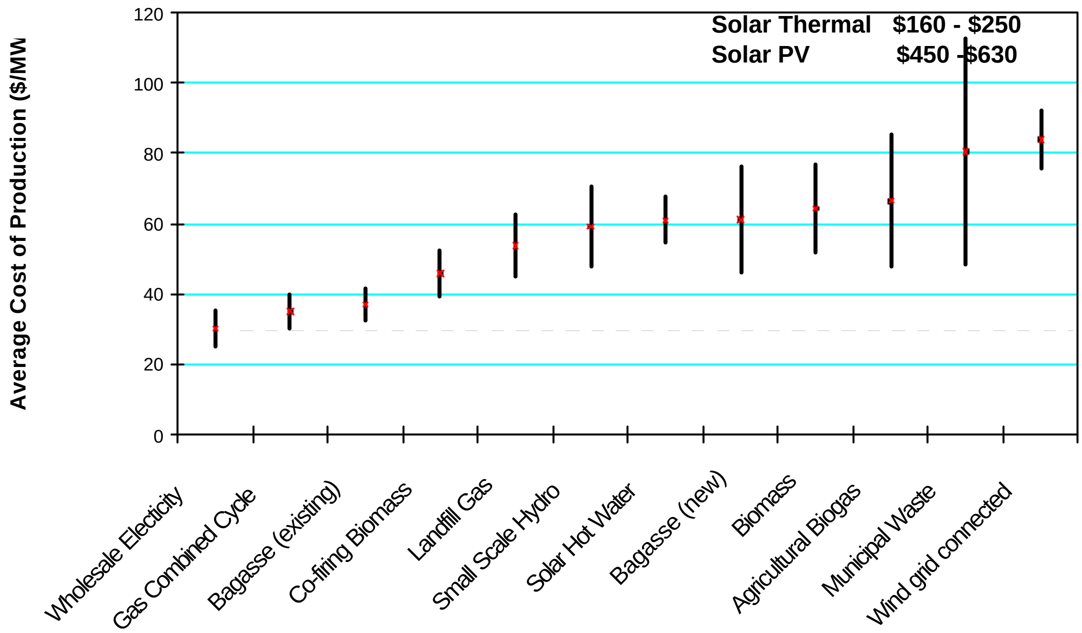
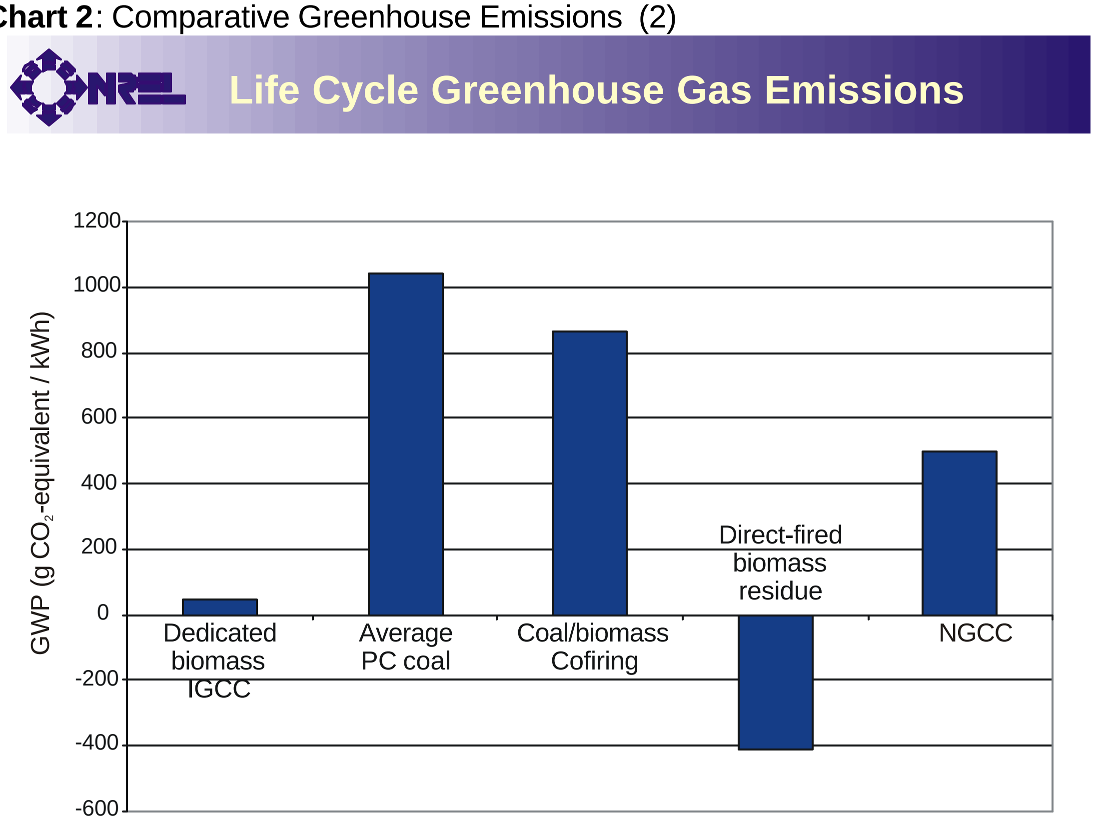


Chart 2: Comparative Greenhouse Emissions (2)



Renewables and Coal: Co-firing for Greater Efficiency

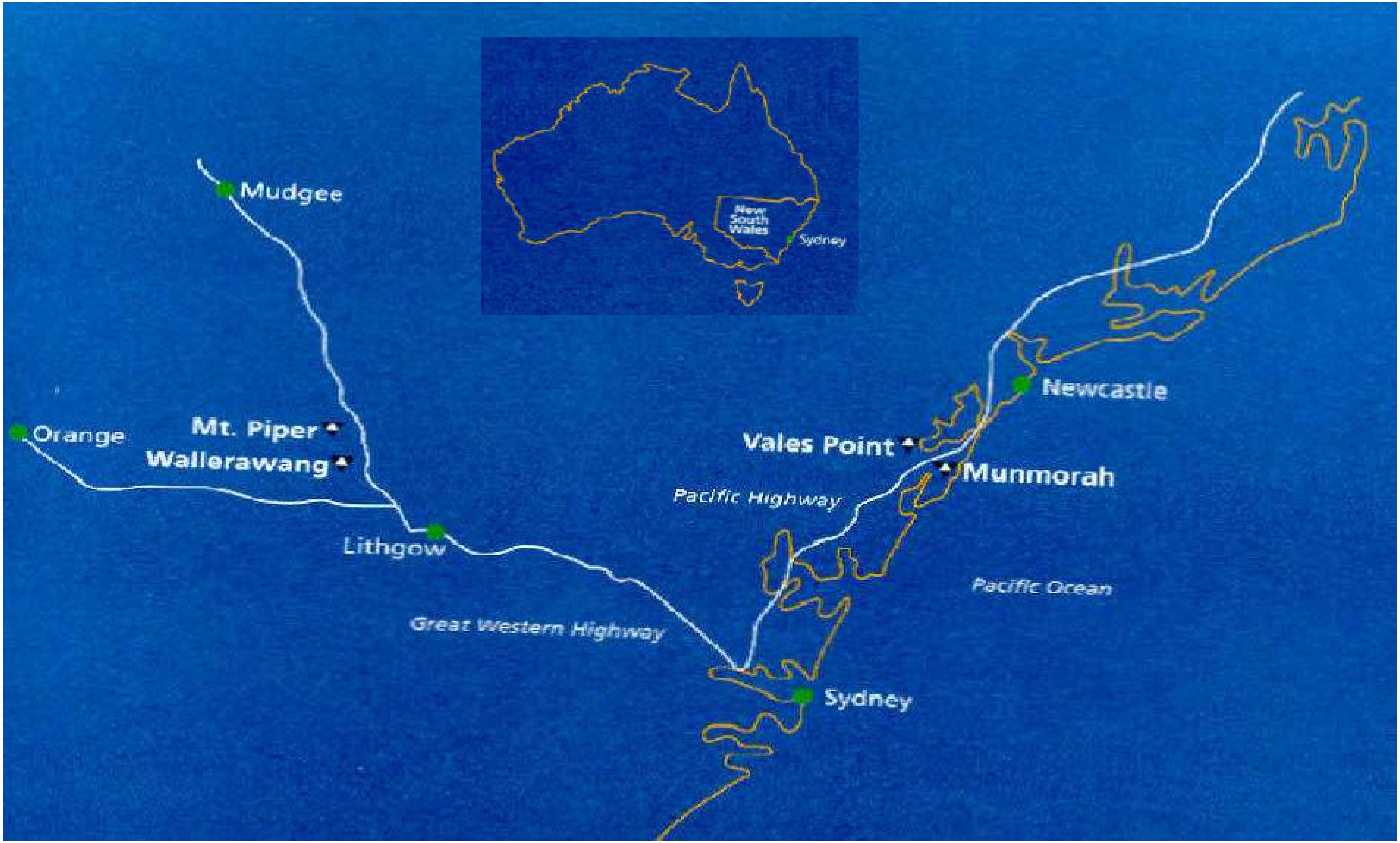
4th APEC Coal TILF Workshop

Kuala Lumpur

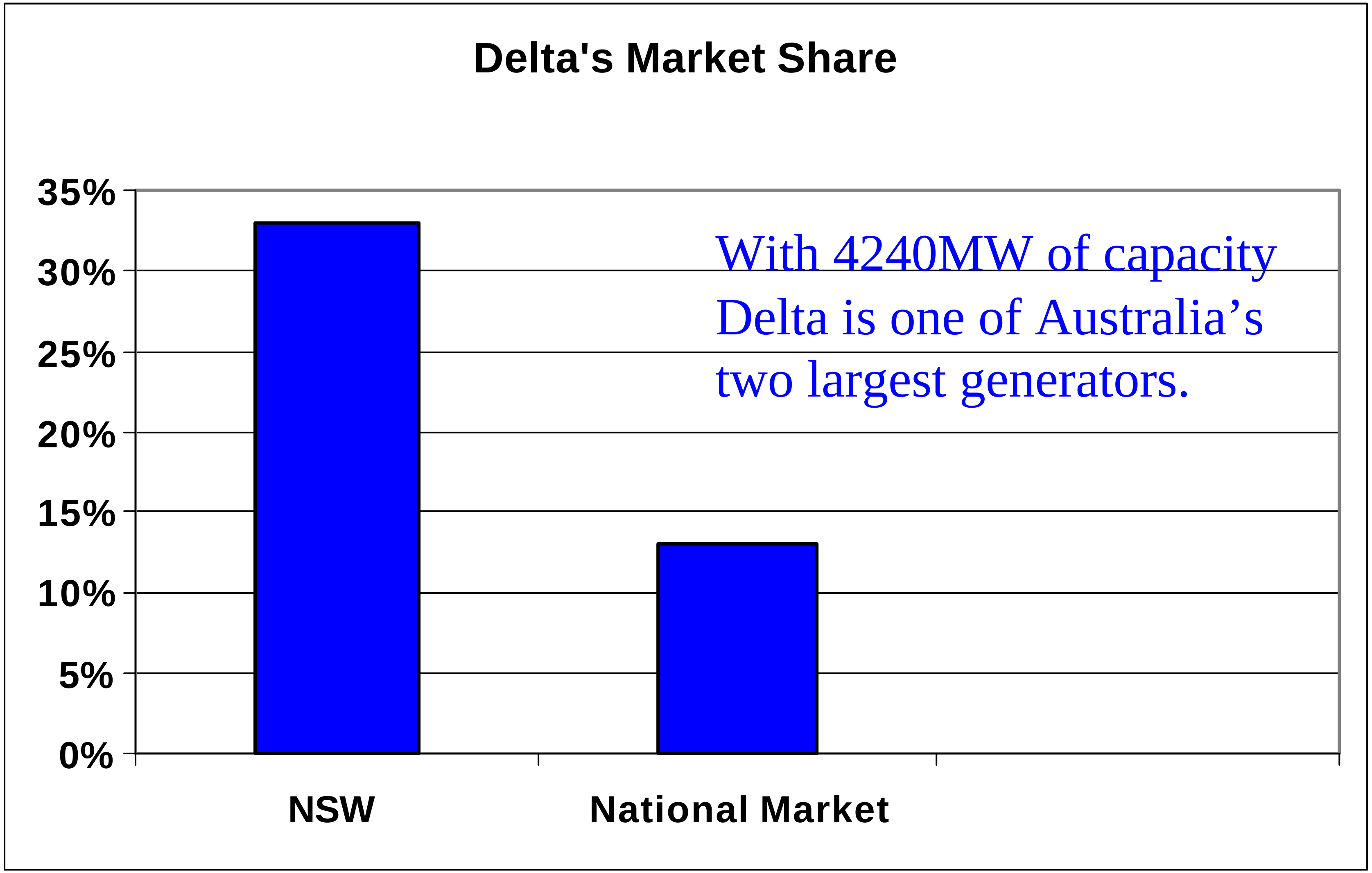
7th and 8th March, 2002

Presented by: Peter Coombes

About Delta Electricity



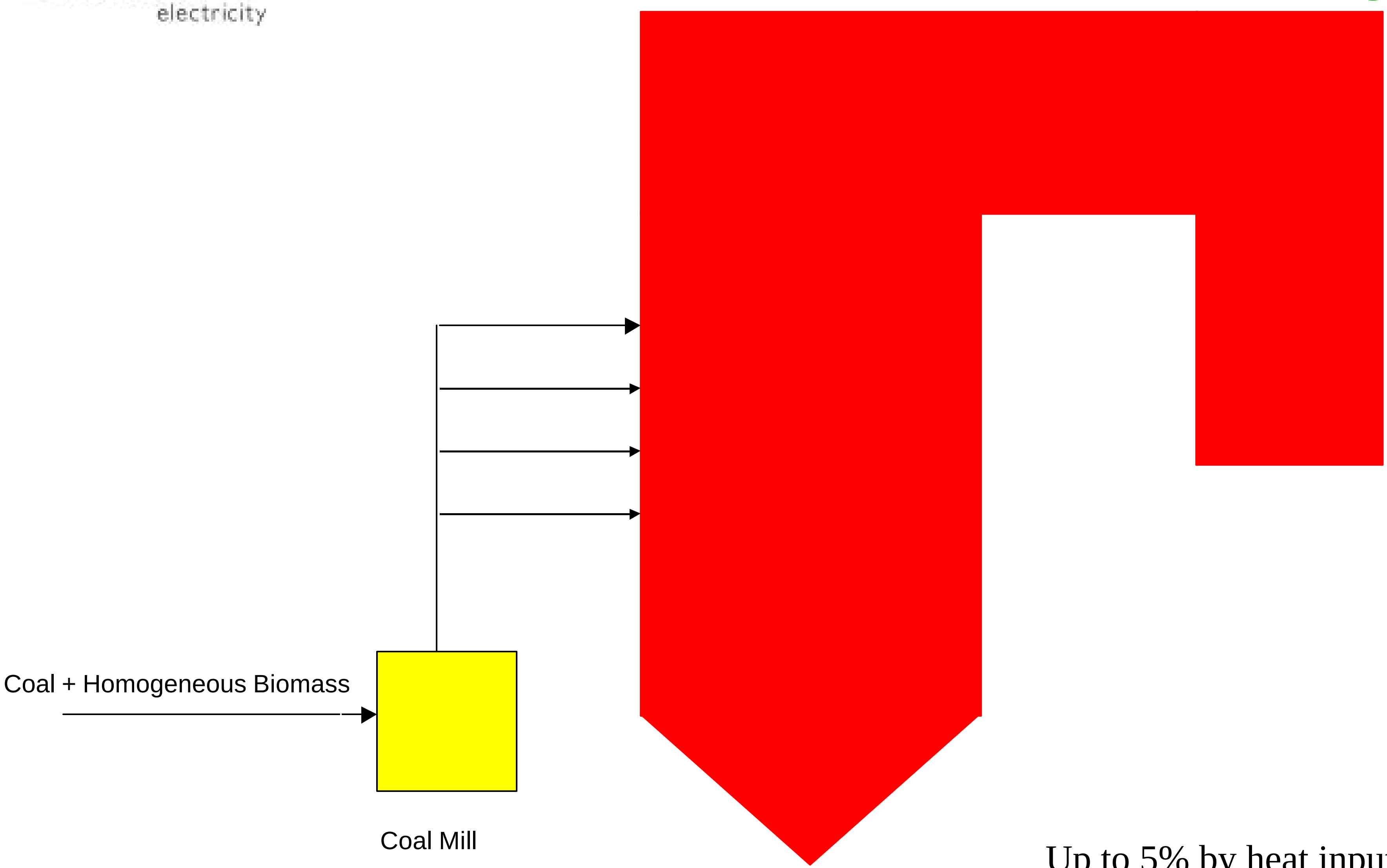
Delta's Wholesale Electricity Market Share



What is Co-firing

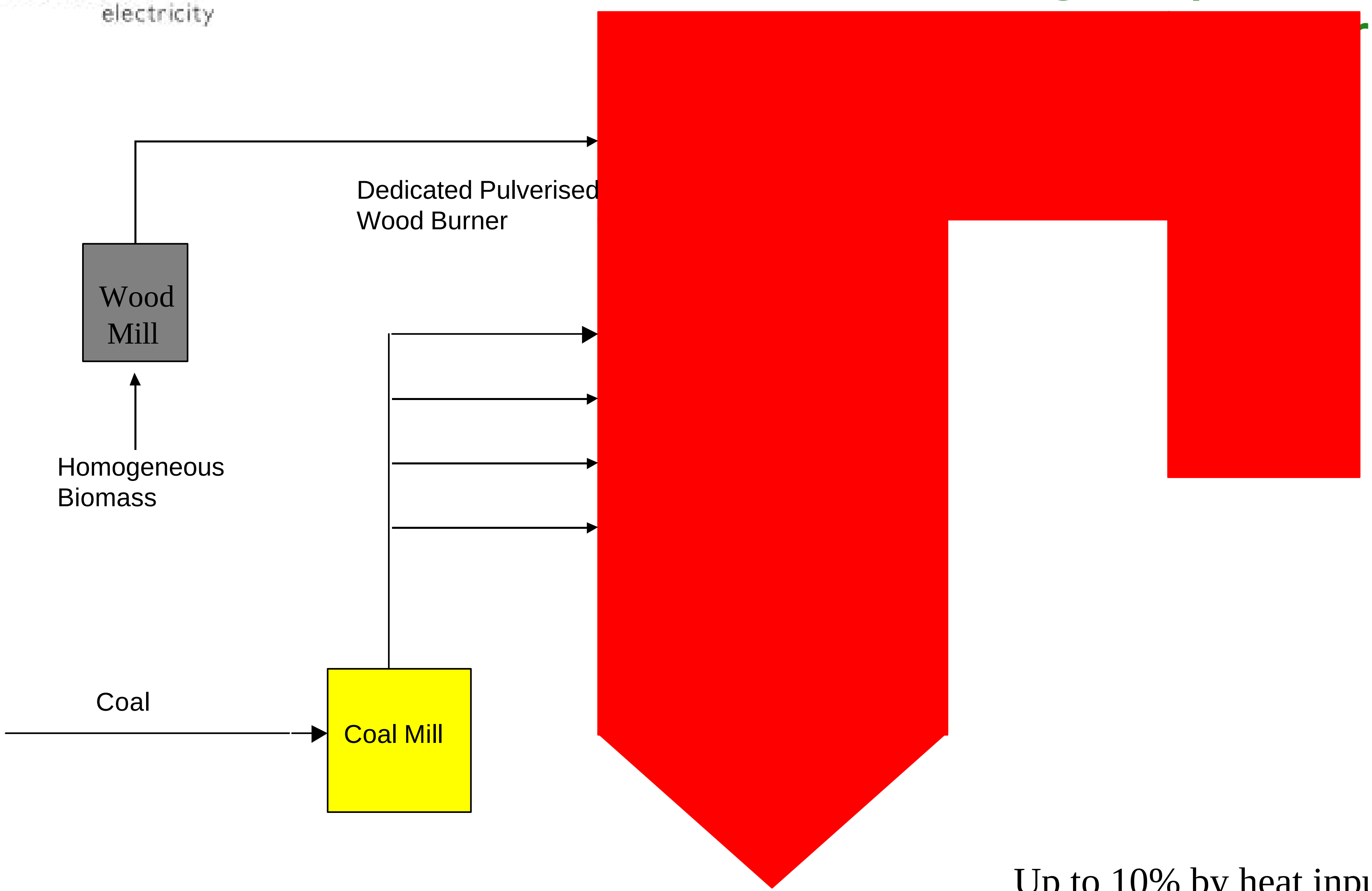
- Utilises existing coal fired power plant
- Combusting small quantities of biomass fuels with coal
- Blended ratio 2 % to 15 % by heat input
- Produces renewable energy
- Reduces greenhouse gas emission
- Promotes recycling & reuse of waste material
- Produces more electricity per unit of fuel than pupose built biomass plant

Direct Co-firing



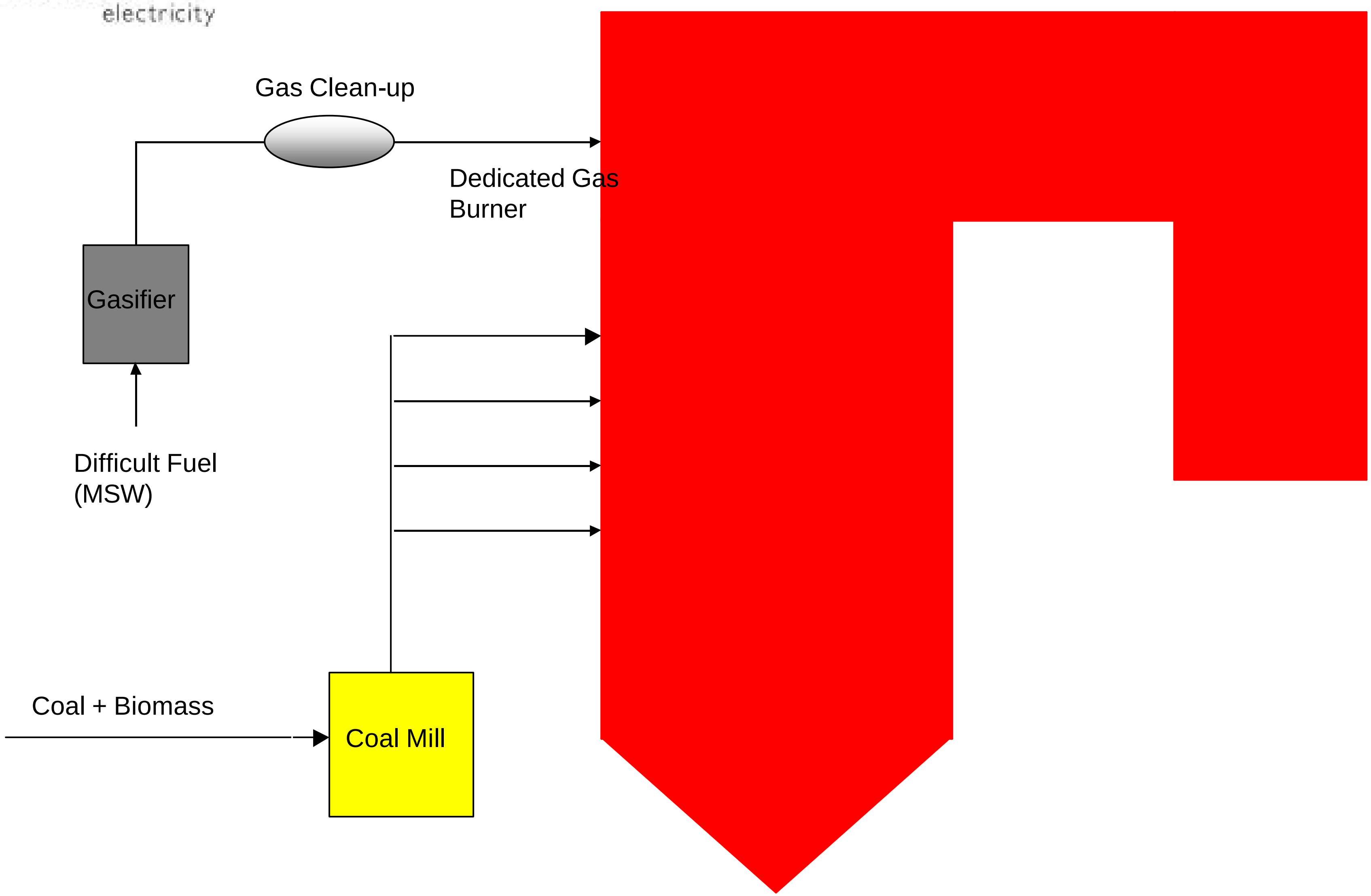
Up to 5% by heat input

Direct Co-firing - Special



Up to 10% by heat input

In-Direct Co-firing



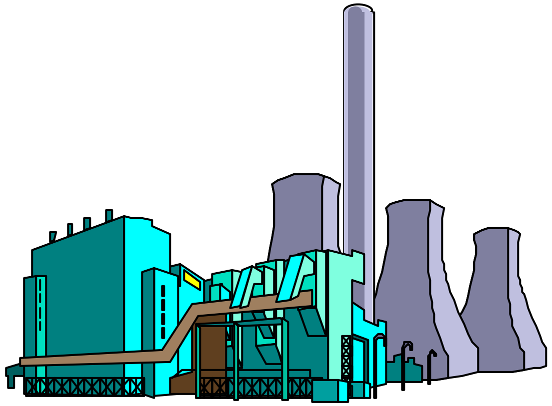
Delta electricity

Carbon Cycle

CO_2

Plant Growth
Sequesters Carbon Dioxide
From the Air

Crop Residue



Power Plant

~~Crop Residue~~

Land fill producing methane

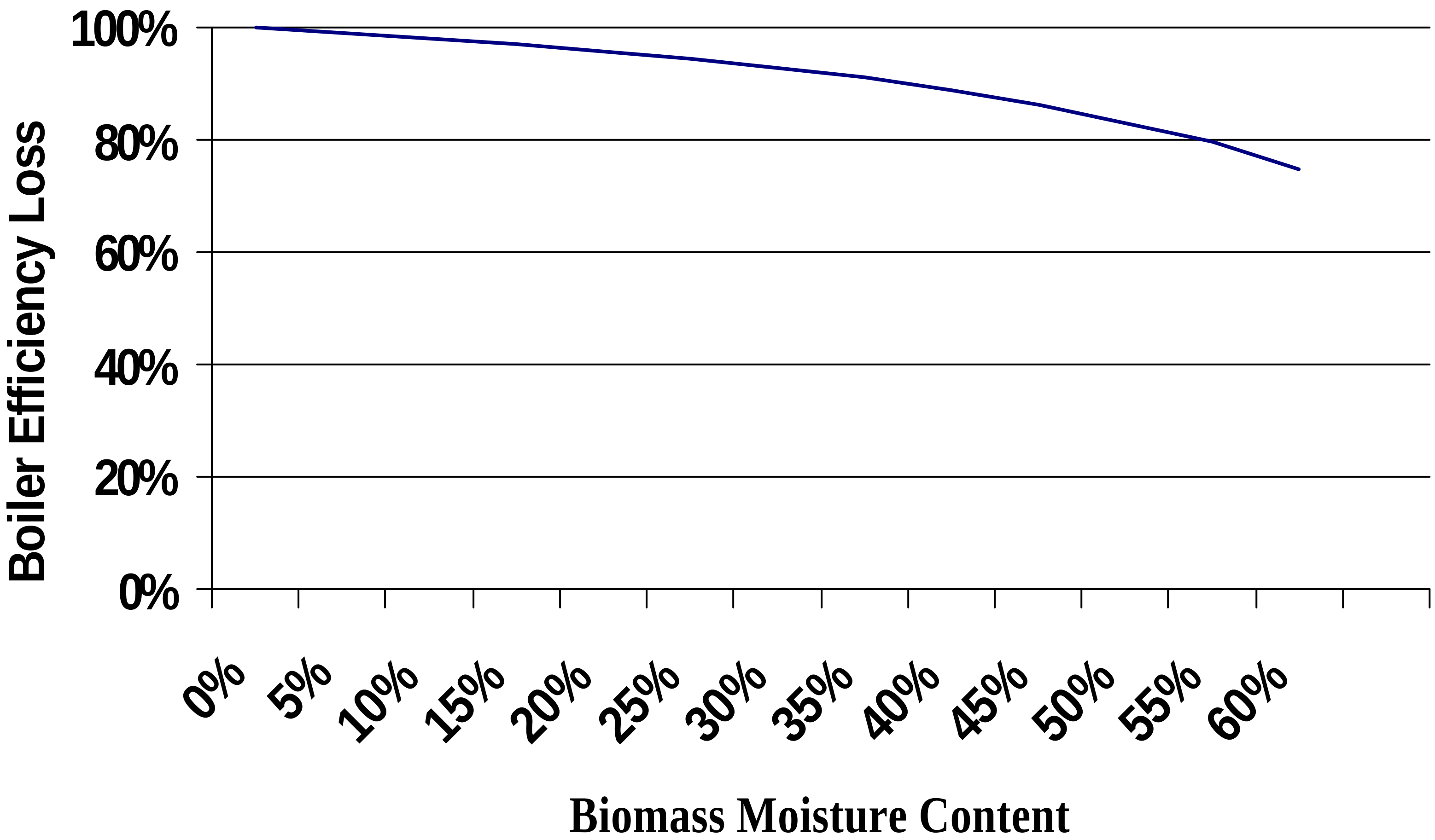
Co-firing Efficiency Benefits

- Large Coal Fired Plants high Efficiency
  - Pressures more than 16 Mpa
  - Temp more than 540 C
  - Split Turbines with reheat cycle
  - 34 - 38 % Efficiency
- Small Biomass Fired Plant
  - Pressures more than 6 Mpa
  - Temp more than 450 C
  - Single Cycle Systems
  - 18 -22 % Efficiency
  - may be appropriate if used for co-generation

Typical Biomass Fuel Specification

	Biomass (wood)	Coal
Gross Specific Energy	18MJ/kg (oven dry basis)	28 MJ/kg (dry)
Moisture	50% (wet wood basis)	10%
Ash Content	4% (oven Dry basis)	25% (dry)
As Fired Gross Specific Energy	9MJ/kg	25MJ/kg
Bulk Density	0.25 - 0.5 t/m3	0.7 –0.9 t/m3
Energy Density	~4 GJ/m3	~20 GJ/m3

Fuel Moisture Impacts

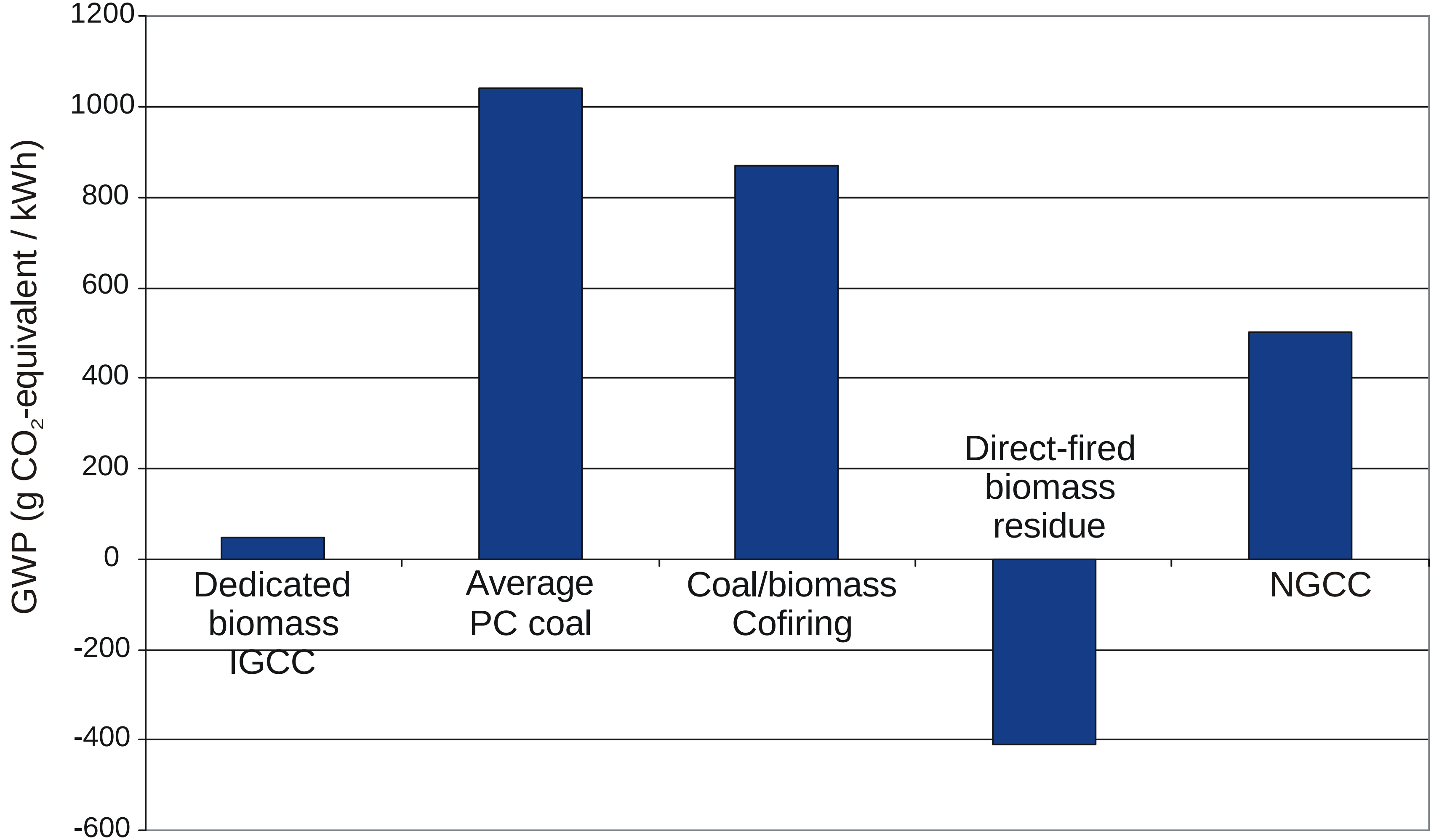


Fuel Selection

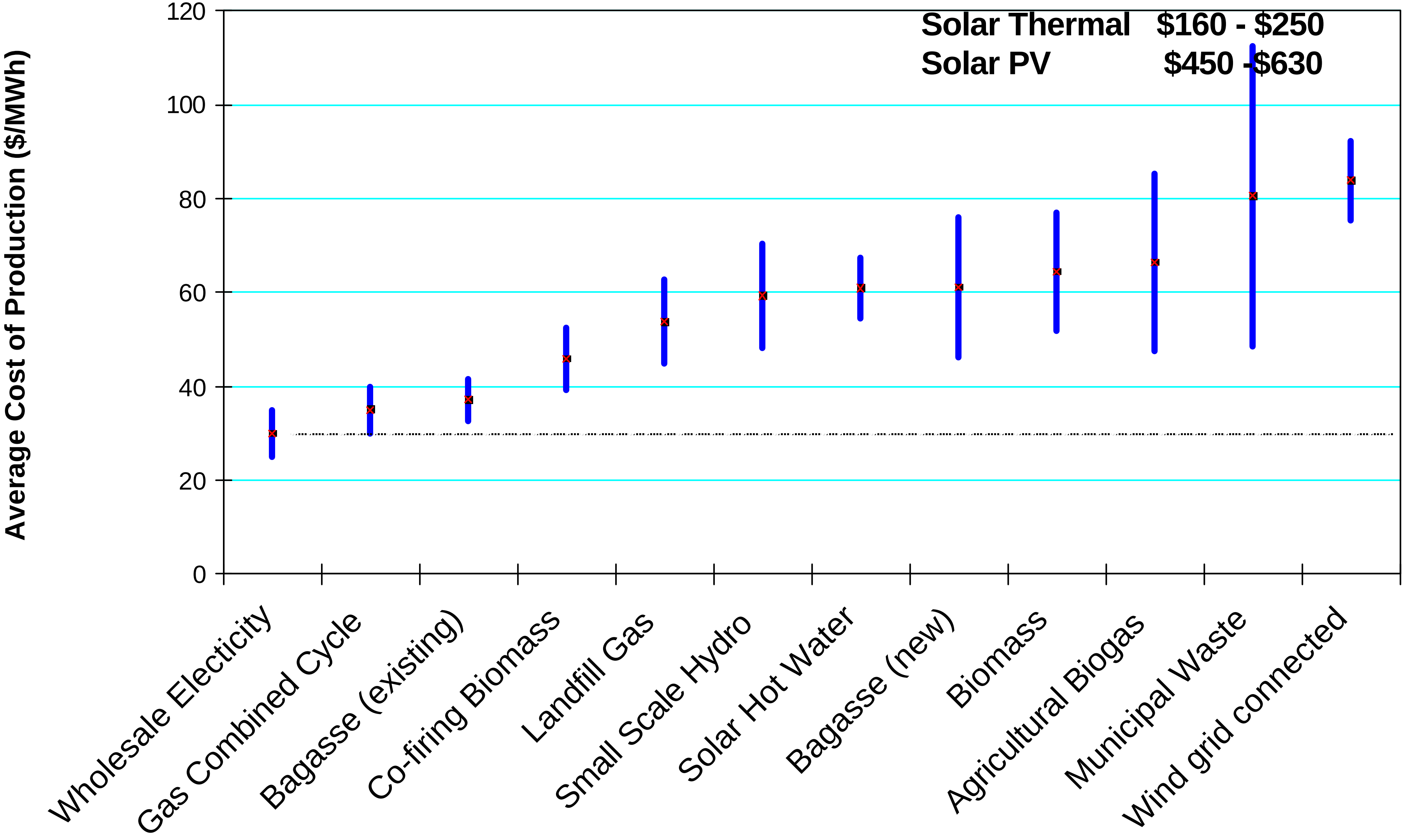
- Economics are transport driven
- Fuels usually low cost by-products of value added process
- Supports waste utilisation
- Greenhouse abatement when co-firing 5% (by energy)
  - Avoided land fill 5 %
  - Renewable sources 5 %

10%

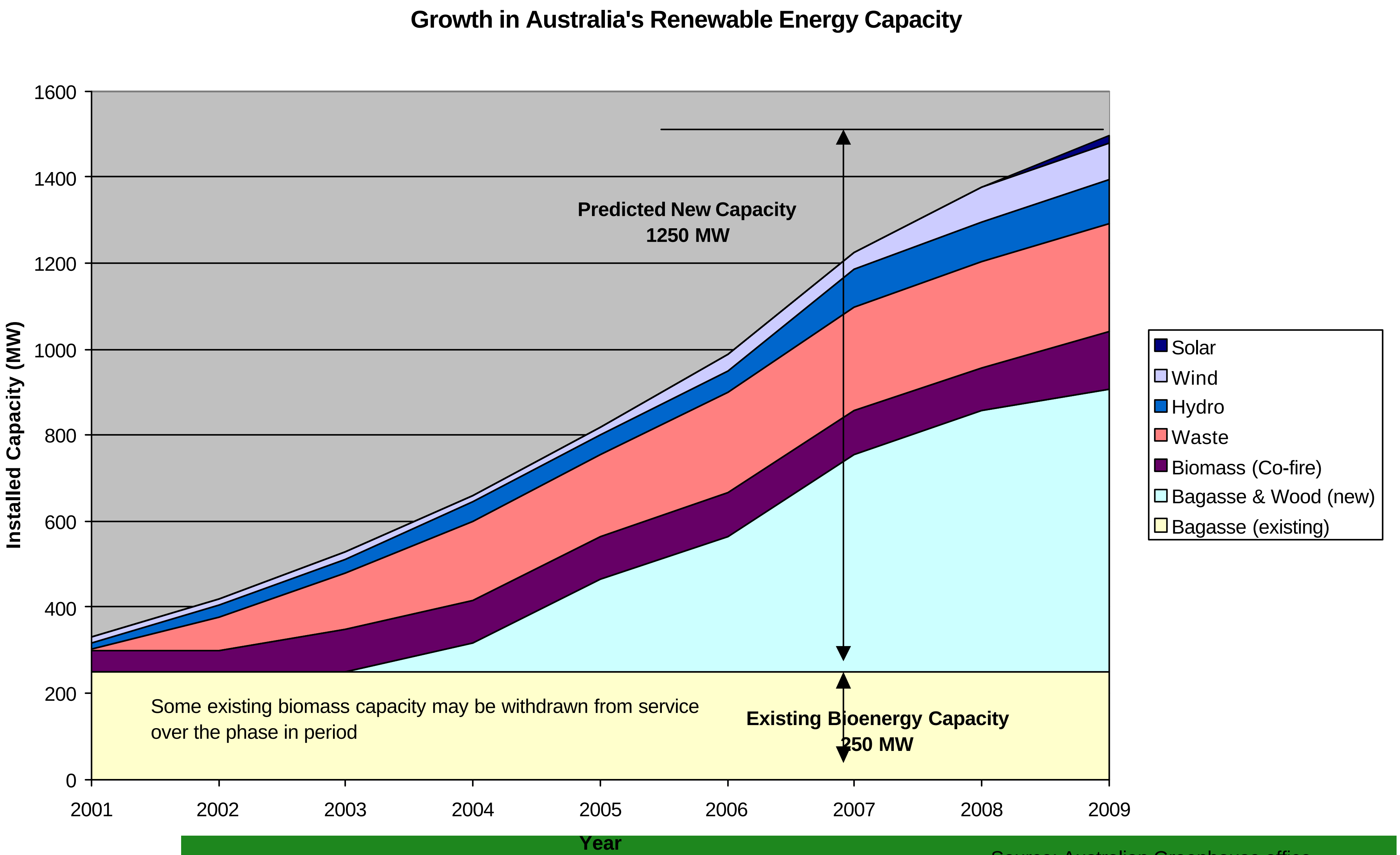
Life Cycle Greenhouse Gas Emissions



Electricity Production Costs for Various Technologies



Growth in Australia's Renewable Energy Capacity



Source: Australian Greenhouse office

Australia’s Co-firing Energy Capacity

Coal Fired Power Plant	*Production (GWh)*	*Plant With suitable Coal Mills (GWh)*	*1 % of production (GWh)*
NSW	60,000	20,000	200
Queensland	40,000	40,000	400
Victoria	40,000	0~50	50

Biomass Resource Requirement ~ 600,000 tpa

Regulation

- Regulation ensures fuel use which:
  - are renewable, or
  - avoids methane production though land fills
  - does not contain environmentally harmful contaminants
  - does not promote unsustainable activities
- Fuels Recognised by the Regulator:
  - construction & demolition timber wastes
  - agricultural by-products
  - weed species
  - saw mill residue

Delta electricity

Wallerawang Power Station

2 x 500 MW Pulverised Coal Units

Delta's Approach to Biomass Fuel Purchasing

- Only use biofuels from sustainable sources
- To target biomass fuels deemed to have no viable alternative use.
- To ensure that biomass fuels are accredited by renewable energy regulators.
- To know the source of the biomass fuel.
- To Conduct Regular Auditing of the suppliers and sources of fuels
- To analyse potential biomass fuels to determine their suitability for purpose.

Wallerawang Co-firing Facility

- Fuel Receival and conveying system

- Fuel of wood residue currently going to land fill

- Fuel supply business promotes re-use of higher value wood wastes material

Wood Chip & Coal Fuel Feed

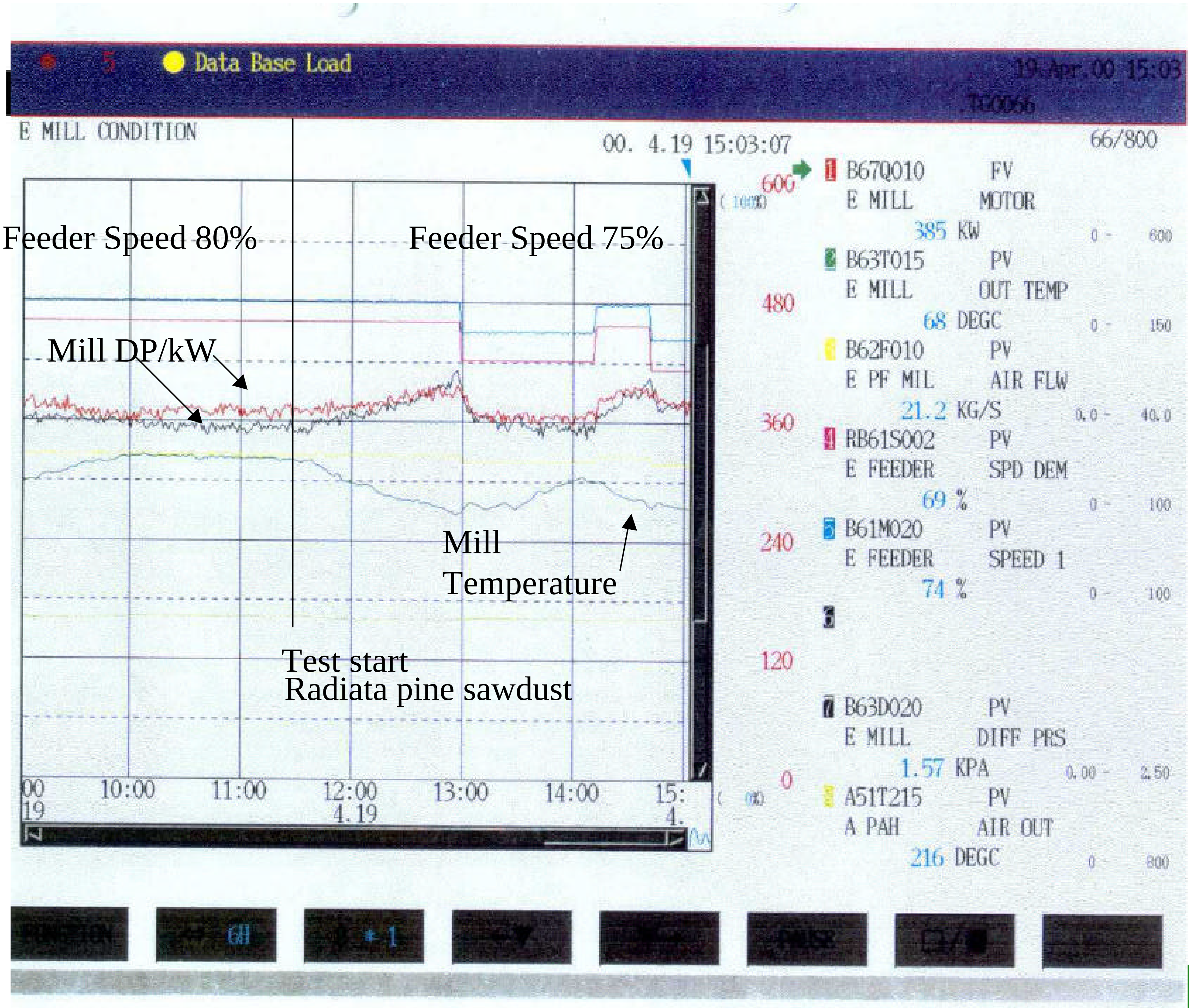
Materials Handling and Mill Performance Trials

Materials Handling:

- Metering on to existing conveyors only way to ensure consistent blend ratio.
- Good mixing observed on coal conveyor after chute gate drops.

Wood Fuel

Woodchip sample ex coal crushing mill


Data Base Load
19 Apr.00 15:03
E MILL CONDITION
00. 4.19 15:03:07
66/800
Feeder Speed 80%
Feeder Speed 75%
Mill DP/kW
Mill
Temperature
Test start
Radiata pine sawdust
600
480
360
240
120
0
10:00
11:00
12:00
4.19
13:00
14:00
15:
B67Q010 PV
E MILL MOTOR
385 KW 0 - 600
B63T015 PV
E MILL OUT TEMP
68 DEGC 0 - 150
B62F010 PV
E PF MIL AIR FLW
21.2 KG/S 0.0 - 40.0
RB61S002 PV
E FEEDER SPD DEM
69 % 0 - 100
B61M020 PV
E FEEDER SPEED 1
74 % 0 - 100
B63D020 PV
E MILL DIFF PRS
1.57 KPA 0.00 - 2.50
A51T215 PV
A PAH AIR OUT
216 DEGC 0 - 800

Fuel Analysis

Ultimate Analysis (% DAF)

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Specific Energy (MJ/Kg) (dry)	19.34	19.72	19.01	18.70	26.60

The focus of co-firing research is on:

Operations

- Char burnout
- Ash deposition ;
- Storage related issues (in particular drying);
- Handling and fuel processing
- Safety related issues
  - - low heating rate pyrolysis in pulveriser units

Emissions Prediction

- Sampling Flue Gas from laboratory combustion of fuel samples
- Timber treated with preserving chemicals
- Engineered timber products containing adhesives

Conclusions

- Co-firing practical & economic if close to fuel sources
- Can reduce greenhouse gas and other emissions
- Regulation important to unsure use of appropriate fuels